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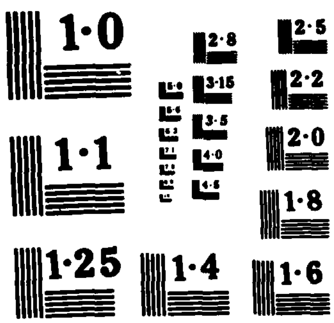

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MEMORANDUM REPORT BRL-MR-3483

INFLUENCE OF MUZZLE BRAKES UPON THE TRAJECTORY OF FIN-STABILIZED PROJECTILES

Edward M. Schmidt
Fred J. Brandon
Sharon C. Pearson

December 1985

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US ARMY BALLISTIC RESEARCH LABORATORY
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The dispersion of groups of fin-stabilized projectiles fired from high velocity cannon was measured for cases with and without a muzzle brake in place. The data clearly show degradation in precision due to the presence of the device. Diagnostic experiments and analyses were performed which indicate that the difficulties arise mainly due to gasdynamic loads within the muzzle device influencing both the projectile motion and sabot discard. Muzzle device design modifications are suggested to solve the problems.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

I. INTRODUCTION

The use of large caliber, high velocity cannon on lightweight vehicles is currently being considered to meet the firepower and mobility needs of light forces in a number of the world's armies. To mount these cannon on the host vehicle, it is often necessary to reduce recoil loads. A classical technique to do this is through the use of a muzzle brake. These devices (Figure 1) use baffles or turning vanes to recover momentum from the propellant exhaust gases. Typically, a well-designed brake can reduce the total recoil impulse imparted to the gun by 20-30%.[1 2] However, the incorporation of such devices on a gun tube can change the launch dynamics of the system. In the present report, the influence of a muzzle brake upon the dispersion of a cannon firing a fin-stabilized, high velocity projectile is examined. The source of disturbance is identified through a series of tests. Finally, techniques are suggested to reduce launch interactions.

The placement of a recoil brake on the muzzle of a gun tube can introduce a number of perturbations to the launch cycle. For large caliber weapons, muzzle devices are generally quite massive. This added mass changes the static flexure of the tube, alters the tube vibrations in fire-on-the-move, and influences the tube and projectile dynamics during the firing event. The presence of baffles near the projectile or sabot component flight paths can lead to mechanical interactions. One feature common to all muzzle brakes is the three-dimensional nature of their geometry. In order to attach the baffles to the gun tube, a set of cowl plates are used. For tank guns, these cowls serve an additional function. By directing the exhaust plume in the horizontal direction, scouring of ground material by the high velocity flow is limited and obscuration reduced. The geometry of the muzzle hardware produces a three-dimensional propellant gas flow within and external to the device. In turn, this flow can interact with the projectile as it passes through the muzzle region.

The magnitude of launch disturbance induced by a muzzle brake is illustrated by the dispersion patterns obtained for two series of firings of ten rounds from a high velocity cannon (Figure 2). For the bare muzzle case, the dispersion meets the specifications (nominally set to unity in arbitrary units); however, when the muzzle device is in place, the dispersion triples. In these tests, the muzzle brake was a three-baffle design (Figure 1). The projectile was fin-stabilized and launched with a single ramp sabot (Figure 3). The cannon was a heavy-walled Mann barrel; thus, it would be expected that the influence of brake mass would be minimal. To test this hypothesis, an equivalent, gasdynamically benign mass was used in place of the muzzle brake and the firings repeated. The resulting shot group returned to specifications. Apparently, the source of the launch perturbation is the enhanced gasdynamic loadings within the brake. For the remainder of the report, experimental and analytic efforts to examine the effect will be considered.

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1. *K. Oswatitsch, "Flow Research to Improve the Efficiency of Muzzle Brakes," R 6601, Kaiser Wilhelm Institute for Flow Research, Goettingen, Germany, July 1943.*

2. *F. Smith, "Model Experiments on Muzzle Brakes," R 2/66, RARDE, Ft. Halstead, UK, June 1966.*

II. GASDYNAMIC INTERACTIONS

The flow within the muzzle device (Figure 1) has quadrilateral symmetry about the horizontal and vertical planes. It would be expected that venting through the lateral openings would produce a rapid pressure decrease in the horizontal direction. While vertically, the confinement provided by the closed cowls would maintain high pressures on the upper and lower surfaces. For some muzzle brake configurations, the strong circumferential pressure gradients within the device have been reported[3] to be sufficient to damage projectile fins. This was not observed in the present tests. When the flow impinges upon baffle surfaces, strong shock waves are generated which propagate in toward the axis. As the round moves through the brake, there are two major categories of gasdynamic interaction that may be envisioned: first, the high velocity, reverse flow may impart a transverse velocity to the round[4] and, second, the sabot discard process may be altered in a manner which enhances interference.[5] At present, techniques to compute the details of this type of three-dimensional, unsteady, internal flow are only just becoming available[6] and are not capable of estimating interaction with the projectile and sabot components. To treat the present problem, a combined analytical/experimental approach is taken.

Linear theory has been used to estimate the effect of muzzle gasdynamic loads upon the trajectory of fin-stabilized projectiles.[4] Basically, the flow is approximated to be quasi-steady and the fins are taken to be the dominant aerodynamic surfaces. The technique has been shown to correctly depict the magnitude of enhanced loads within a circular channel placed on the muzzle of a gun launching a flechette round. In the present application, an identical approach is taken to estimate the contribution to dispersion of enhanced fin loads within the muzzle brake. The pertinent gun tube exit conditions are:

$$M_e = 2.1$$

$$P_e = 58 \text{ MPa}$$

$$T_e = 1190 \text{ K}$$

The equivalent expansion ratio into the muzzle device (accounting for venting) is $A_c/A_e = 3.5$, which yields for the channel flow:

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3. *L. MacAllister, Private Communication, BRL, APG, MD, April 1984.*

4. *E.M. Schmidt, K.S. Fansler, and D.D. Shear, "Dispersion of Fin-Stabilized Projectiles: Launch Gasdynamics," 2d International Symposium on Ballistics, ADPA, Alexandria, VA, March 1976.*

5. *E.M. Schmidt and D.D. Shear, "Aerodynamic Interference during Sabot Discard," Journal of Spacecraft and Rockets, Vol. 15, No. 3, AIAA, New York, NY, May-June 1978, pp. 162-167.*

6. *J.C. Buell and G.F. Widhopf, "Three-Dimensional Simulation of Muzzle Brake Flowfields," Paper No. 84-1641, AIAA, New York, NY, June 1984.*

$$M_c = 3.15$$

$$P_c = 9.5 \text{ MPa}$$

$$T_c = 810 \text{ K}$$

and the relative Mach number over the projectile is

$$M_r = 0.6$$

Using the distribution in projectile angle of attack at separation from the gun,[7] the increase in dispersion may be estimated. Based upon the units of Figure 2, this increase is 0.4, a number significantly lower than actually observed.

To examine the influence of internal gasdynamics upon the subsequent sabot discard, an experiment was conducted using a set-up similar to that described previously.[5] Six orthogonal x-ray stations were positioned over the first 9.0 m of the trajectory to observe the discard process and initial projectile dynamics. The projectile then enters the BRL Transonic Range[8] where free flight motion is measured for a distance of 206 m. Six full data rounds were fired: three with the triple baffle brake in place and three with a bare muzzle.

A comparison of the mean sabot discard trajectories is presented in Figure 4. The figures in this sequence present the relative locations of the sabot and projectile averaged over all sabot components and data rounds for each muzzle configuration. It is apparent that the presence of the brake acts to retard sabot discard. At the first x-ray station, the sabot for the bare muzzle case has pitched cleanly up and off the projectile. While at the same location, the sabot for the muzzle brake case still remains essentially in the assembled position. By the second station, both cases show the sabot clearing the projectile with the brake case being closer. This behavior is maintained throughout the discard. While the discard is obviously retarded by the presence of the brake, there does not appear to be a sufficiently drastic alteration in the dynamics to explain the observed dispersion growth. Examination of the details of individual discard sequences produces a more valuable correlation.

Data for the discard process with the bare muzzle are presented in Figure 5. The sequence (Figure 5a) is similar to the mean data. In this case, the trajectories of two opposing components are plotted for each x-ray station. The discard is clean and reasonably symmetric. Once a sabot component clears the projectile, it does not reimpinge. Comparison of the pitch angles relative to the projectile for all four sabot components reinforces the symmetry

7. *P. Plostins, "Launch Dynamics of APFSDS Ammunition," 8th International Symposium on Ballistics, ADPA, Alexandria, VA, October 1984.*

8. *W.K. Rogers, "The Transonic Free Flight Range," U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, BRL Report 849, February 1953 (AD 13358).*

argument (Figure 5b).

With the muzzle brake in place, there is a change in the discard (Figure 6). The sequence (Figure 6a) shows the position of the sabot components in the vertical plane at stations 2, 3, and 4. After first moving laterally, the bottom component rotates and reimpinges on the projectile. The impact is asymmetric in that the upper component does not touch. This type of mechanical impact is a significant source of perturbation[9] which can lead to subsequent aerodynamic asymmetries in discard. The rear ramp of the sabot is configured in a manner that the reverse flow within the muzzle brake will tend to hold the components in the assembled position. This neutralizes any initial lateral motion imparted to the sabot components due to elastic decompression upon release from the gun tube and changes the overall discard process. The distribution in pitch angles of the sabot components for a discard with the muzzle brake (Figure 6b) shows that there are significant differences between the various components. Such geometric asymmetries produce aerodynamic asymmetry which can further perturb the flight path. The combination of impact of the sabot components with the projectile and subsequent aerodynamic interference may be sufficient to explain the observed growth in the dispersion of the system when the muzzle device is in place. To minimize the influence of the muzzle brake, it is necessary to consider the gasdynamic as well as the mechanical interactions that may occur.

III. MUZZLE BRAKE DESIGN FOR PRECISION

Reduction of muzzle brake induced gasdynamic interactions requires designs which minimize asymmetry, thus decreasing the magnitude of interactions. Further, the overall length of the device should be constrained, thereby, reducing the duration of interactions. For the existing brake, the latter concept was easily tested. The length of the brake (and its efficiency) was decreased by cutting off the outer two baffles producing the dispersion pattern (for a ten round group) illustrated in Figure 7. Obviously, the dispersion is closer to the specified value; however, the efficiency of the brake has decreased from a value of 14% for the triple baffle design to 7% for the single baffle case.

In order to restore efficiency, a larger single baffle brake has been designed (Figure 8) with an estimated efficiency of 23%. The design attempts to minimize any gasdynamic interactions along the axis by providing a "quasi-symmetric" initial expansion. Horizontally, the propellant gas exhausts through the vents. Vertically, the device provides an initial turning angle which is 90° , or the sa. e as in the horizontal direction. The cowl is shaped in a fashion which prevents the shock generated off the surface from reaching the axis. The baffle is flat (although a chamfered baffle could provide higher efficiency and perhaps enhanced strength). The projectile hole is cut with an angle of the core flow from an undisturbed exhaust jet. While it is recognized that a normal shock will form on the baffle, the turning angle through the projectile hole will develop an expansion which should weaken the

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9. *E.M. Schmidt, "Disturbance to the Launch of Fin-Stabilized Projectiles," Journal of Spacecraft and Rockets, Vol 19, No. 1, AIAA, New York, NY, Jan-Feb 82, pp. 30-35.*

shock. The resulting brake is similar to devices which may be observed on vehicles parked in a number of ordnance museums around the world; however, in this case, it has been designed with the saboted projectile as the prime motivator. At present, the device has not been fabricated or tested.

IV. SUMMARY

Data are presented which demonstrate that the use of muzzle brake on high velocity cannon can interfere with the launch of fin-stabilized ammunition. In particular, it appears that the interaction is associated with enhancement of muzzle gasdynamic loads within the brake. Analysis tends to support the alteration of sabot discard dynamics as the major source of perturbation. Techniques are presented for the design of muzzle brakes with acceptable level of efficiency which do not significantly degrade precision.

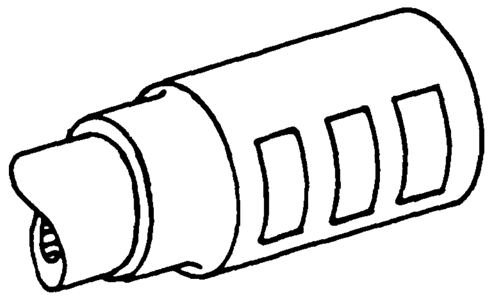


Figure 1. Schematic of Triple Baffle Brake

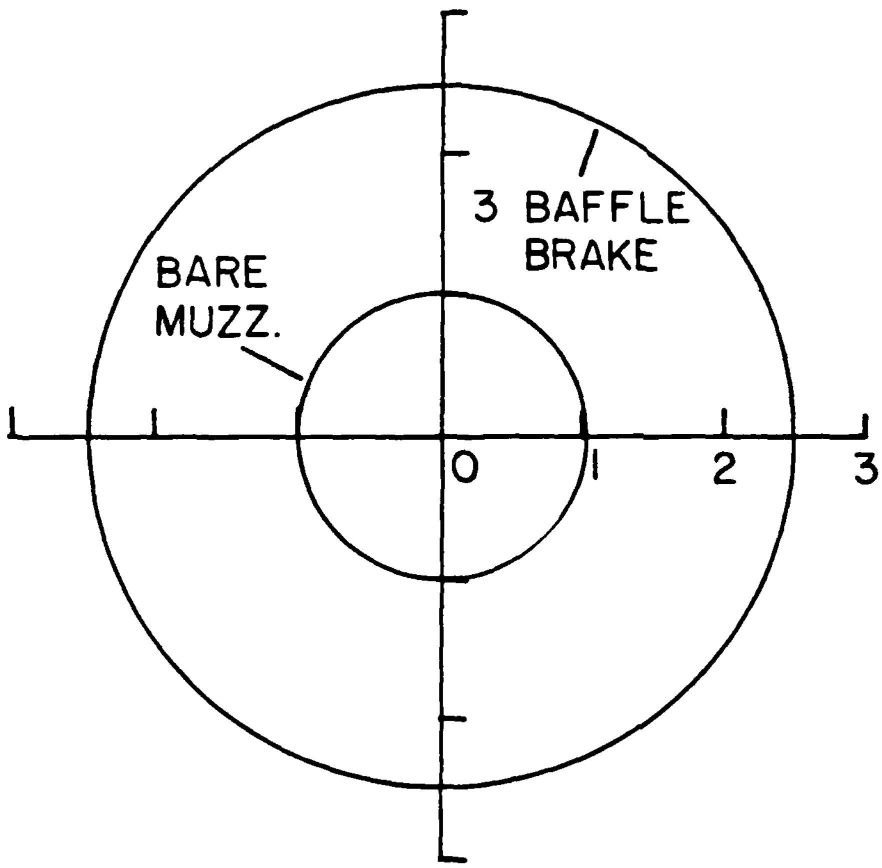


Figure 2. Dispersion Patterns (in arbitrary units) for Cases with Bare Muzzle and Triple Baffle Brake

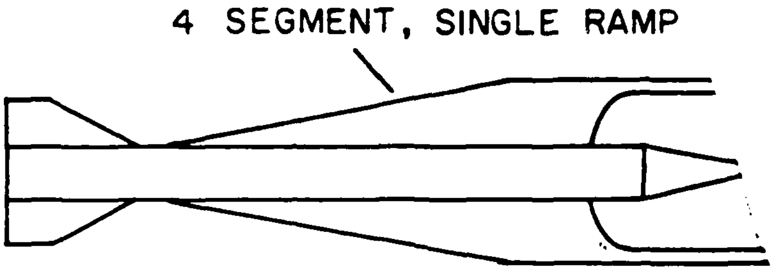


Figure 3. Schematic of Test Round

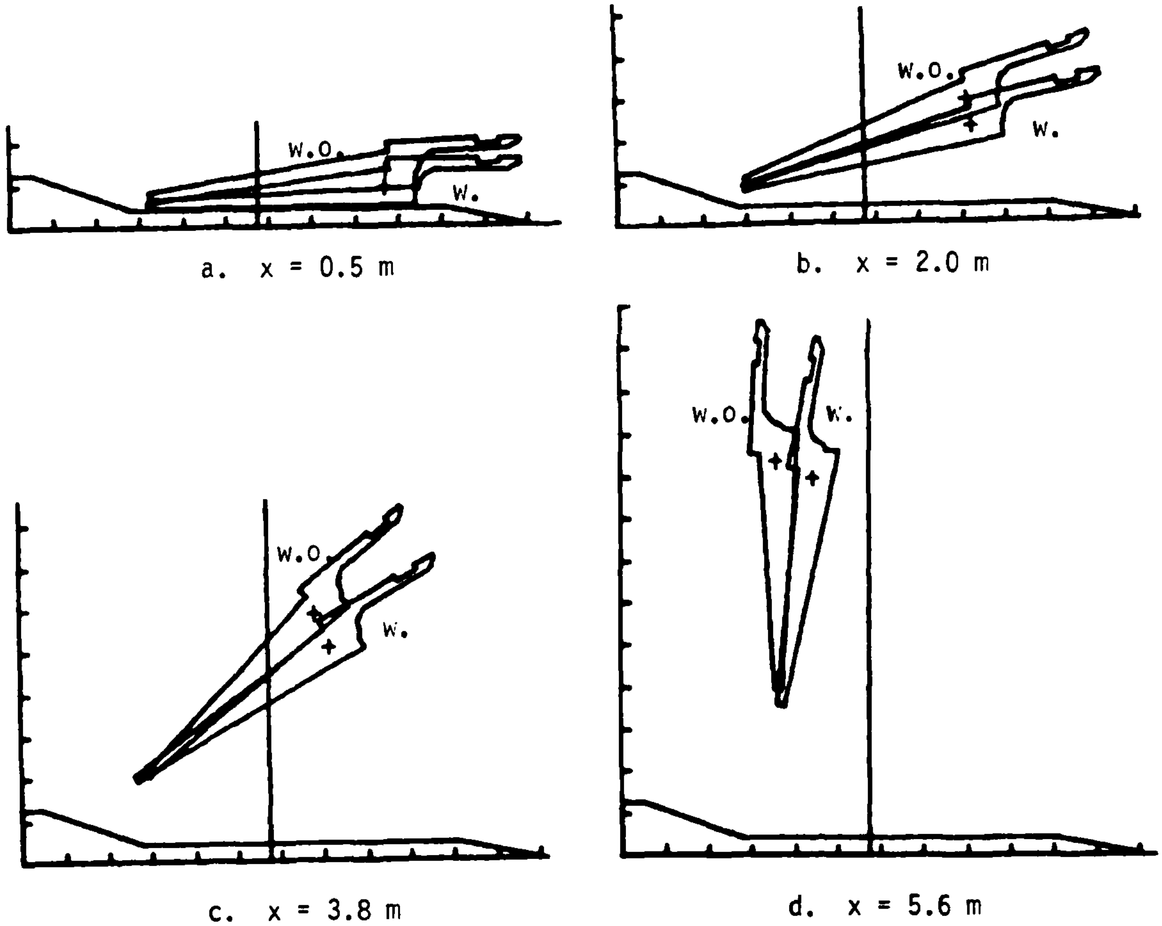
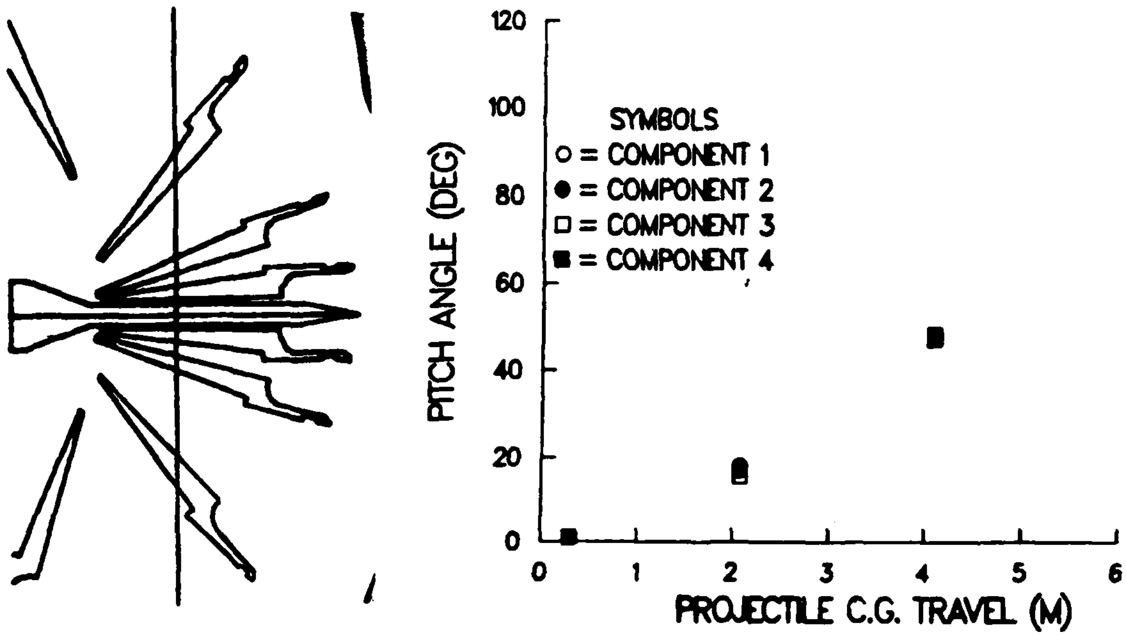
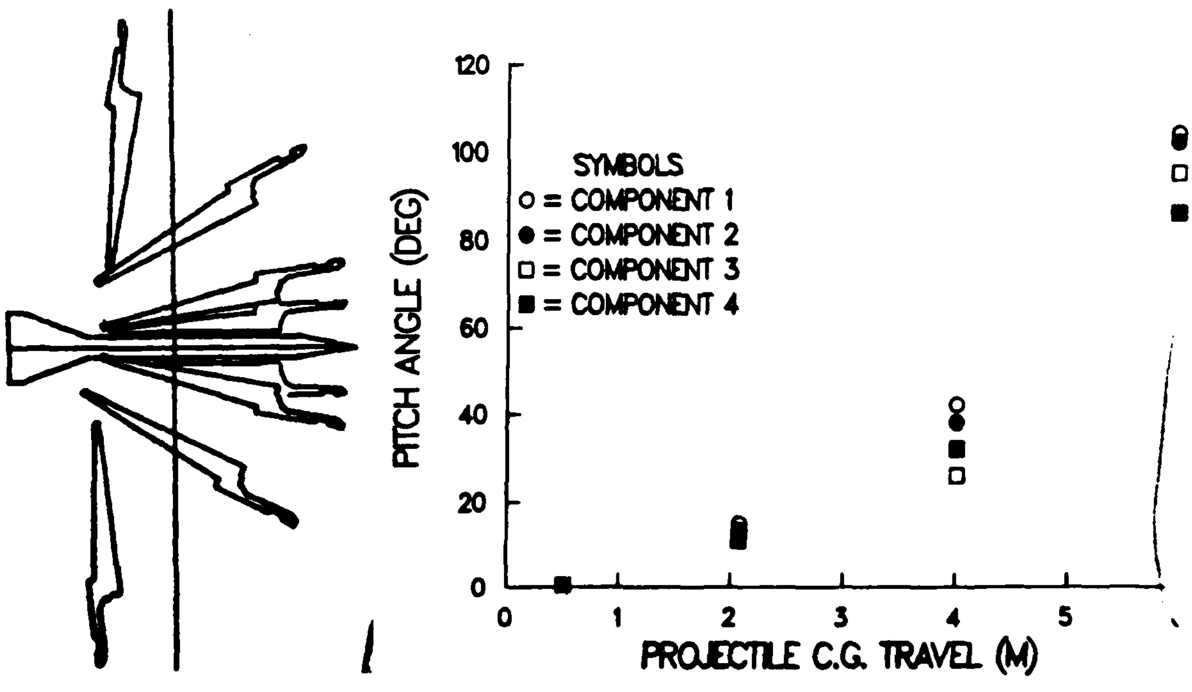


Figure 4. Average Position of Sabot Components Relative to the Projectile for Cases With and Without Triple Baffle Brake in Place



a. Vertical Plane Discard b. Sabot Component Pitch Angle

Figure 5. Bare Muzzle Sabot Discard



a. Vertical Plane Discard b. Sabot Component Pitch Angle

Figure 6. Sabot Discard with Brake

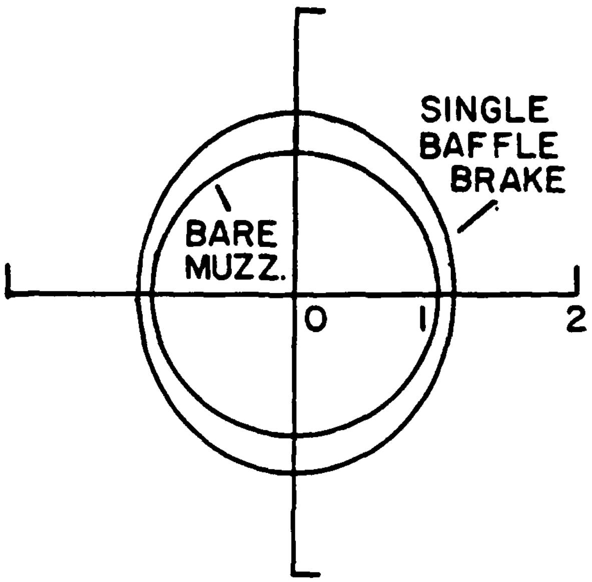


Figure 7. Dispersion Patterns (in arbitrary units) with Bare Muzzle and Single Baffle Brake

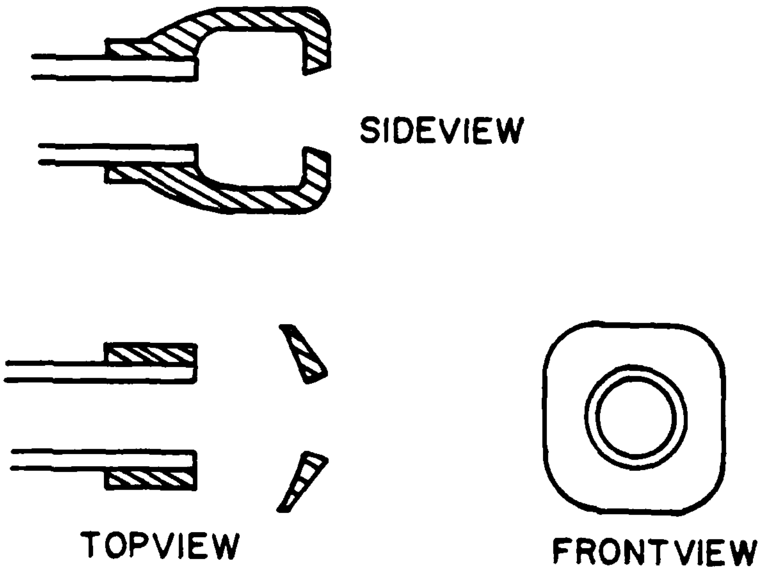


Figure 8. Schematic of Typical Low Disturbance Brake

REFERENCES

1. K. Oswatitsch, "Flow Research to Improve the Efficiency of Muzzle Brakes," R 6601, Kaiser Wilhelm Institute for Flow Research, Goettingen, Germany, July 1943.

2. F. Smith, "Model Experiments on Muzzle Brakes," R 2/66, RARDE, Ft. Halstead, UK, June 1966.

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8. W.K. Rogers, "The Transonic Free Flight Range," US Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD, Report 849, February 1953 (AD 13358).

9. E.M. Schmidt, "Disturbance to the Launch of Fin-Stabilized Projectiles," Journal of Spacecraft and Rockets, Vol. 19, No. 1, AIAA, New York, NY, Jan-Feb 1982, pp. 30-35.

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